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TOWARDS AN INTERNET-OF-THINGS FRAMEWORK FOR ASSISTING QUALITY-CONTROLLED-LOGISTICS DECISION MAKING WITHIN THE FRESH PRODUCE SUPPLY CHAIN.

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ABSTRACT

Fresh food is mainly wasted due to overproduction and the natural decay of food quality which cannot be prevented. Hence, actors in the fresh food supply chain are responsible to monitor and control activities that influences the quality of fresh food. The emergence of new technologies such as Internet-of-Things (IoT) creates the opportunity to collect real-time food quality information, which may be used to assist and adapt logistic activities to ensure that food quality remains in the accepted quality limits. The aim of this paper is to identify current knowledge on quality-controlled logistics (QCL) in the fresh produce industry, and to identify whether there are opportunities to implement IoT-technologies, from the perspective of experts working in the fresh produce industry.

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1. INTRODUCTION

Roughly one third of edible fresh food is wasted because the quality has dropped below acceptable limits [1]. Food waste is therefore a global issue. In South Africa it is estimated that the fruit and vegetable commodity group have a significant contribution to food waste, as it contributes 44% to the total food waste [2]. The World-Wide Fund [3] estimated that 50% of fruit and vegetables are wasted during the post-harvest stage, 25% is wasted during process and packaging, and 20% is wasted during the distribution and retailing stages. Two main factors that contribute to food waste are overproduction of produce and the natural decay of food quality which cannot be prevented but is accelerated by poor supply chain management [4].

Food waste could be reduced by implementing quality control in food logistics, meaning that information about attributes which affect food quality, could be used to make better logistic decisions. Recent technological developments make it easier to collect the relevant information regarding food quality attributes. Researchers are investigating the use of Internet-of-Things (IoT) technologies within the food industry, as they believe that IoT will create numerous benefits for the fresh food supply chain [5]. Sundmaeker et al. [6] mention that IoT in the supply chain will create the following capabilities:

1. Better sensing and monitoring of production, crop development, and food processing;
2. Better understanding of environmental conditions, and to gain knowledge about appropriate management actions;
3. More sophisticated processing and logistics operations by actuators and robots;
4. Improving food quality monitoring and traceability by remote controlling the location and conditions of shipment and products; and
5. Increasing consumers' awareness of sustainability and health issues by personalised nutrition and wearables.

Although researchers believe that the use of IoT-technology provides several benefits, there is still uncertainty whether stakeholders in the fresh food supply chain will reap the full benefit and value from IoT technologies, as Sundmaeker et al. [6] state that there are technical and non-technical challenges that need to be addressed.

The aim of this paper is to identify current knowledge on quality-controlled logistics (QCL) in the fresh produce industry, and to identify whether there are opportunities to implement IoT-technologies, from the perspective of experts working in the fresh produce industry. Section 2 provides a summary of literature reviewed on fresh food supply chains, food quality, quality-controlled logistics, and Internet-of-Things within food logistics. Section 3 discusses the data collection and feedback received from experts within the fresh produce industry, and Section 4 concludes this paper.

2. LITERATURE REVIEW

The following section provides a summary of literature reviewed on fresh food supply chains and the use Internet-of-Things within the food industry.

2.1 The complexity of fresh food supply chains

A supply chain consists of actors (companies) that collaborate to put products in the market [7]. Each actor has a series of activities and processes to fulfil to add value to the product so that the consumers are willing to buy the product [8]. Fresh food supply chains usually consist of four stages, as shown in Figure 1. The first stage is called harvesting, where farmers are responsible for the production and harvest of fresh food. After harvesting, food is transported to the second stage, called processing and packaging. Here the fresh food is washed, packaged and stored until it needs to be transported to a distribution centre, which is the third stage. At the distribution centre, fresh food is stored until it must be shipped to the retailer. The last stage is the retailing where the retailer is responsible for selling the fresh food to the consumers.

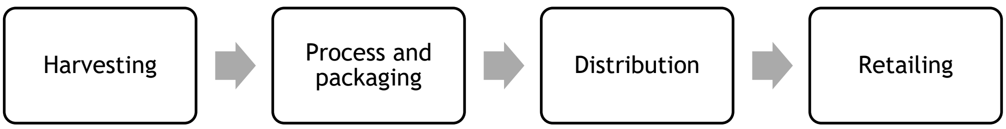

Figure 1: The four stages in a fresh food supply chain.

Fresh food supply chains are classified complex due to various reasons. Although the fresh food supply chain normally consists of four stages, it does not necessarily mean that there are only four actors. The number of actors involved depend on the size and strategy of the supply chain. Van der Vorst et al. [9] explains that actors in fresh food supply chains usually participate in different supply chain processes which means that that they may collaborate with partners that are competitors in other chains. Jonkman et al. [10] further explains that fresh food supply chains are complex because the supply design and performance measurements are highly dependent on product integrity. The reason is that fresh food is perishable by nature, meaning that the products deteriorate rapidly once they have been harvested [11].

Perishability influences the value and the quality of the products [11], and according to Aramyan et al. [12] food quality should be considered as a key performance measurement since it is one of the main characteristics that makes the fresh food supply chain complex.

2.2 Food quality

Food quality is becoming increasingly important to measure and monitor throughout the fresh food supply chain. This is in part due to consumers' expectations on food quality which are becoming a key influence during their purchase decision [8]. It is difficult to measure food quality because (i) each actor in the supply chain has their own perception of quality; and (ii) there are various product and environmental factors involved that influences food quality [13] [14].

To address the challenge of measuring and monitoring food quality, researchers in food science developed the concept of shelf-life. Shelf-life is defined by Jedermann et al. [15] as the 'time span for which fresh food can be stored at a certain reference temperature until it is no longer suitable for human consumption or when the food quality does not meet the freshness requirements of consumers. Shelf-life models can be used to predict the time span that is left in total for transport, storage and display in the shop as a function of the environmental conditions to which fresh products may have been exposed to, if such information is available [4]. The accuracy of the shelf-life model depends on the number of quality attributes that are available to monitor and measure, but Jedermann et al. [15] mention that even the simplest shelf-life model provides great insights on product quality and estimated remaining shelf-life.

2.3 Quality Controlled Logistics

Dani [16] defines logistics as 'the operational component of supply chain management, including the quantification, procurement, inventory management, transportation management, and data collection and monitoring'. In fresh food supply chain management, one can then argue that logistics is the movement of fresh food through the supply chain until it reaches the consumer. What makes fresh food logistics more challenging, is that the movement of products must be in adequate environments to ensure that food quality is retained [17]. Van der Vorst et al. [8] introduced a concept called "*Quality Controlled Logistics*", where they suggest that product quality should be considered to determine the required logistic strategies to implement throughout the supply chain. They proposed to view product quality as a dynamic issue and that one should use time dependent quality information to adapt logistics activities. Van der Vorst [18] continued to improve on this concept and developed key features and the necessary requirements that need to be considered when implementing Quality Controlled Logistics, as shown in Figure 2.

Consumer preference

- Understanding consumer preference of quality attributes.
- Get insigths in product acceptance period for all market segments.

Critical control points (CCP) for quality and logistics

- Get insight in dynamic behaviour of product quality attributes.
- Systematic assessment of CCP that have major impact on product quality and availability in retail outlets.

Product quality measurement and prediction

- Have ability to measure and analyse quality at CCP.
- Have automated quality measuring at CCPs
- Have prediction models to calculate real product quality.

Data logging and exchange of information

- Select local target for quality attributes, reduce variability internally and manipulate product quality in line with market demands.
- Apply quality driven inventory management principles.
- Sort homogeneous small batches, have quality based picking and transport.

Local dynamic or adaptive logistics and quality control

- Use advanced data loggers and techniques to capture relevant information real-time and reliable
- Exchange quality, supply and demand information in chain.

Supply chain management

- Establish full chain collaboration to create demand-driven chains.
- Direct goods to highest value markets and apply efficient replenishment in JIT principles for responsive distribution.
- Use temperature controlled containers and packaging.

Figure 2: Requirements to implement Quality Controlled Logistics (reproduced from [18]).

2.4 Internet-of-Things in food logistics

There is a growing interest in using Internet-of-Things (IoT) technologies in various industries, as it is an emerging technology that is expected to offer promising solutions such as tracking, monitoring and data accessibility to transform the operations within these industries [5]. IoT can be defined as 'a dynamic global network infrastructure with self-configuring capabilities based on standards and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into an information network" [19]. Hence, IoT is a paradigm where objects can interact and cooperate with one another through wired and wireless connection, as shown in Figure 3. The main goal of IoT is to interconnect unique, addressable things to generate and share information across diverse platforms and applications, considering security and privacy issues [19] [20].

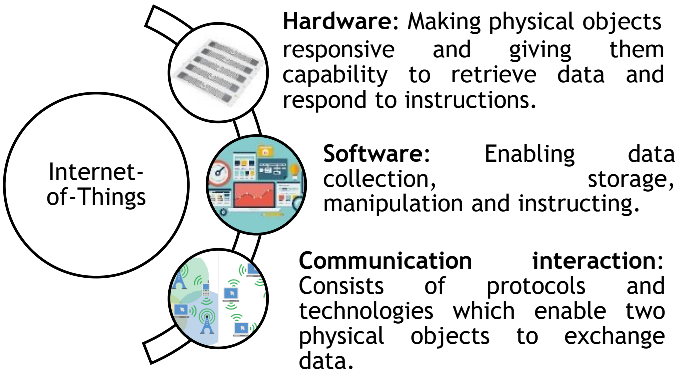

Figure 3: Components of Internet-of-Things.

As mentioned previously, fresh food supply chains can become complex due to the number of actors involved, product quality, and various logistics activities [21]. Several authors studied the potentials of using IoT technologies within the fresh food industry. Da Xu et al. [22] concluded that IoT provides the possibility to improve the traceability, visibility and controllability of food quality and safety throughout the entire supply chain. It can also be used to capture large amounts of data that can be further analysed and used to improve business processes and support decision-making. Sundmaeker et al. [6] mentioned that the use sensor technologies such as humidity, light and ethylene indicators are increasingly used to manage food quality, and temperature sensors are used to monitor the conditions in packing facilities, cooling storages and transportation. Implementing IoT technology in the fresh food supply chain creates the opportunity to base logistics decisions on the dynamic change of food quality over time.

Researchers estimate that the implementation of IoT technologies creates the opportunity to tackle food waste as well. Smart sensors can be used to monitor temperature, freshness, respiration and ethylene gas to detect food spoilage. This information then can be used to determine accurate shelf-life and redirect products to closer locations depending on the remaining shelf-life. Thus, it reduces the chance that food is wasted before it reaches the consumer [23]. Additionally, Vasseur [24] explained that IoT sensor data and analytics is a promising start to gain insights on identifying elements that contributes to food waste. It allows supply chain actors to take the necessary action to control or mitigate the elements to reduce food waste. He also discussed that linking IoT monitoring with task management encourage behavioural change and efficiency to minimize food waste. Integrating IoT monitoring with mobile devices and apps, allows staff to take just-in-time actions to protect food and minimize waste. Notifications and alerts via email, SMS, or automated phone calls can be used to take notify staff about anomalies in the supply chain.

From the literature that has been reviewed, it was identified that fresh food supply chains are defined as unique and complex especially since food quality should be considered when planning the logistic activities. Researchers developed the concept of Quality Controlled Logistics to incorporate food quality with the logistic activities. Furthermore, researchers believe that IoT-technologies can be used to collect data on food quality that can provide more accurate information to assist Quality Controlled Logistics. In the next section the paper will discuss opinions and feedback from experts working in the fresh produce industry to acknowledge whether they are familiar with Quality Controlled Logistics as well to receive their opinion on the use of IoT-technologies in the fresh produce industry.

3. EXPERT INSIGHTS REGARDING QUALITY CONTROLLED LOGISTICS AND INTERNET-OF-THINGS

The following section describes the approach used to receive feedback from experts within the fresh produce industry as well as an analysis and discussion on the feedback they provided.

3.1 Data collection technique and approach

Selecting the best technique to collect data often depends on the (i) purpose of data collection; (ii) type of information required; (iii) resources available; and (iv) evaluation of the collected data [25]. The purpose for data collection within this paper was to gain relevant knowledge on the following topics:

- identifying essential logistics decision regarding fresh produce quality and the requirements or inputs necessary for these decisions;

- establishing ways to use IoT-technologies to enhance Quality Controlled Logistics; and
- identifying essential requirements or considerations to implement IoT in the fresh produce industry.

An interviewer questionnaire was designed with the purpose to ask semi-structured questions to experts working in the fresh produce industry. Interviewer questionnaires refer to those questionnaires where the interviewer physically meet participants and ask the questions face to face. Semi-structured questions are a mix of open and closed questions, meaning the participant has the opportunity to provide feedback based on a predetermined selection of answers, as well as providing answers based on the participant's freedom.

3.2 Setting and sampling

FRUIT LOGISTICA is a fresh produce exhibition, annually in February in Berlin, the capital of Germany. It covers every sector of the fresh produce industry, provides the latest innovations and offers networking and contact opportunities to global companies. From the 7th until the 9th of February 2018, companies from multiple countries presented their products and services such as (i) multiple fresh products; (ii) technical systems; (iii) logistics; and (iv) other services. Further information can be found on the FRUIT LOGISTICA website: https://www.fruitlogistica.de/en.

During the exhibition, companies were asked to complete the questionnaire. Fifteen companies were willing to participate. The participants who completed the questionnaires were from companies that provided (i) logistic solutions for transportation and warehousing management; and (ii) technical solutions that can be integrated with transport, warehouse and quality management, as shown in Figure 4 on the left side. The participants who partook, were either marketing and sales agents, managers within their field of expertise, or the company CEO, as illustrated in Figure 4 on the right side.

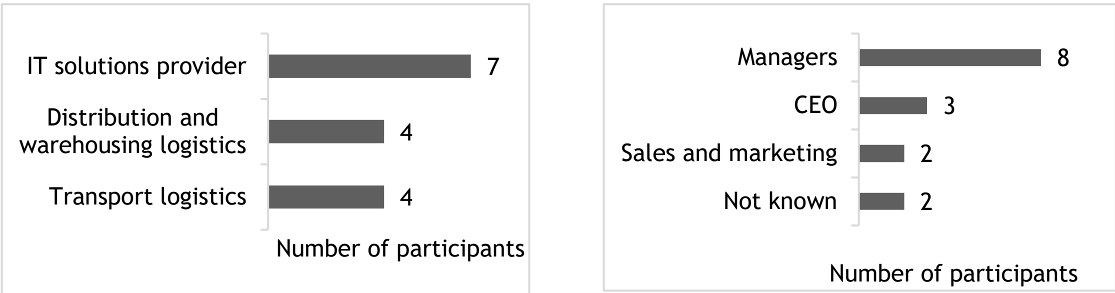

Figure 4: Participants feedback profile in terms of company type (left) and role within the company (right).

3.3 Feedback

The questionnaire was designed to collect feedback regarding two themes: (i) Quality Controlled Logistics; and (ii) Internet-of-Things (IoT). The first set of questions were designed to identify whether companies consider fresh produce quality within their logistic activities in the supply chain, and which logistic activities influence produce quality before it reaches the end-consumer. These questions were designed to receive feedback based on predetermined answers, meaning the participants were able to select the answers that they believed were most suited for the question. Each time a specific answer was selected, it was counted to determine the most popular answers.

The second set of question were designed to determine whether companies within the fresh produce industry believe that IoT-technologies can create value within the supply chain, and to determine what they believe are requirements and challenges to implement IoT-technologies throughout the supply chain. These questions were designed to receive feedback based on the participant's knowledge and opinion on the topic. Similar feedback from the participants were clustered together and the most frequent responses were included in the feedback analysis.

3.3.1 Feedback regarding Quality Controlled Logistics

The first question related to identify general types of logistic decisions that need to be considered in the fresh produce industry. From the feedback shown in Figure 5, temperature management, and transport modes and route scheduling are general logistics decisions to consider within the fresh produce industry since more than half of the participants responded that they consider it as general logistic decisions. Managing inventory and stock levels and considering storage practices can also be noted as general logistic decisions, as more than five participants responded that they also focus on these logistic decisions within their companies. Less than five participants said that they consider order picking, shelf space allocation, layout design, and replenishment policies are general logistics decisions within their company.

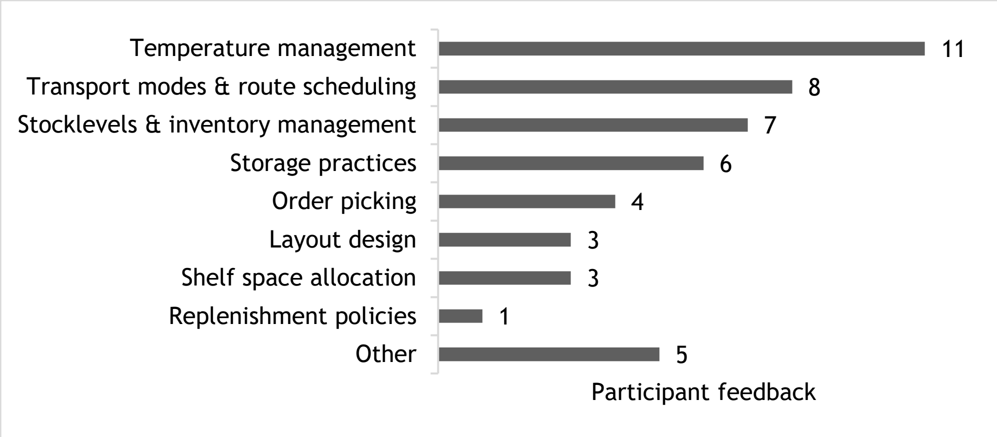

Figure 5: General logistics decisions to consider within the participant's company.

Questions two and three were asked to identify key logistic decisions that influences produce quality after harvest, as well as acknowledging critical quality control points provided by the participants feedback. From Figure 6, the feedback provided by the participants are relatively equal. This suggests that all four decisions mentioned in the question, have influence on produce quality once it has been harvested. Figure 7: Critical quality control points. Figure 7 illustrates that the participants believe that the conditions during transportation as well as storage conditions in either warehouses or distribution centres are critical quality control points in the fresh produce supply chain.

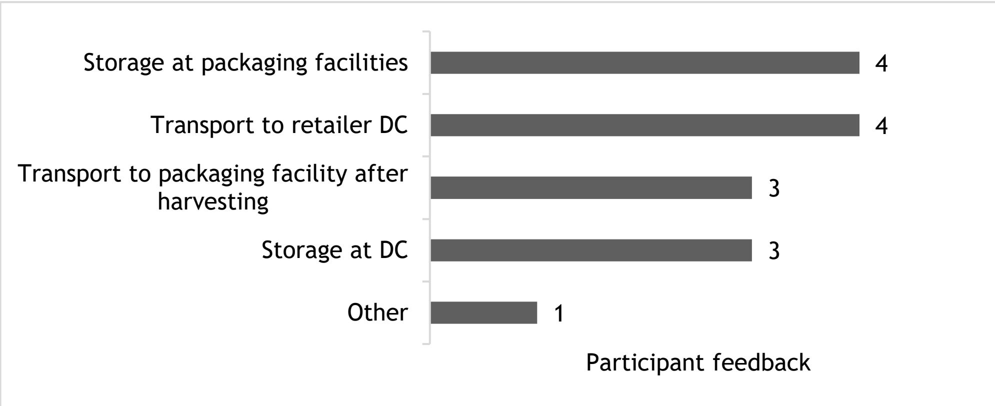

Figure 6: Logistic decisions with the most influence on quality after harvesting.

Figure 7: Critical quality control points.

The purpose of questions four and five were to determine what environmental conditions influence produce quality, and which of these environmental conditions were considered as important conditions to monitor throughout the supply chain. Figure 8 shows the environmental conditions that the participants suggest are important to measure throughout the supply chain. Temperature and relative-humidity are considered as extremely important environmental conditions to monitor, as stated by at least 13 participants. Ethylene is also considered as a condition to monitor, since four participants said it is extremely important to monitor it, and seven participants said it is moderately important. Other environmental conditions such as the lighting, shock and vibration during transportation, as well as controlled atmosphere during transportation and storage were mentioned by the participants.

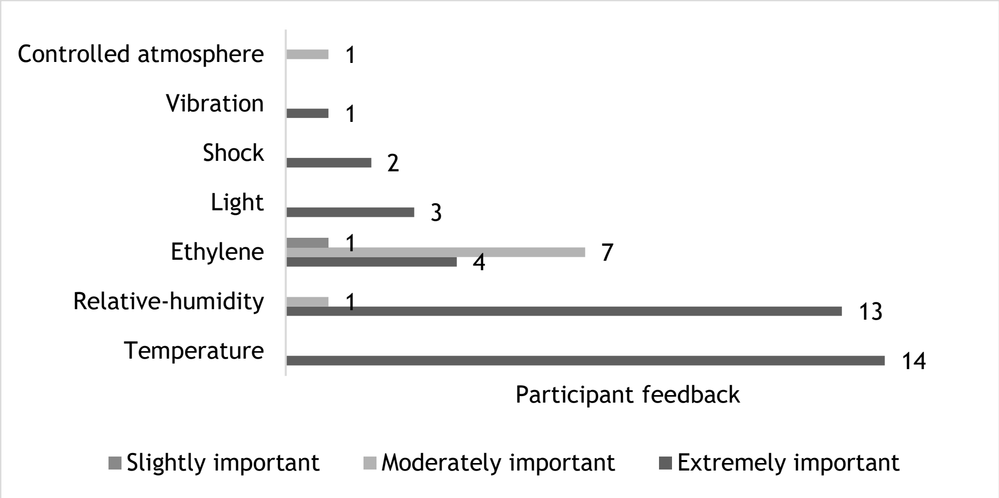

Figure 8: Importance of monitoring the defined environmental conditions.

The next question related to the level of influence predetermined logistic activities have on fresh produce quality. A list of logistic activities was given to the participants and they had to select the level of influence each activity has on produce quality. From the feedback shown in Figure 9, it is noted that majority of the participants mentioned that transport scheduling and routing have an extreme influence on produce quality. Activities such as transport mode selection, distribution network design, and storage mode and capacity were also highlighted as activities that have extreme influence on produce quality. Participants also mentioned that activities such as loading capacity and order picking planning had moderate influence on produce quality.

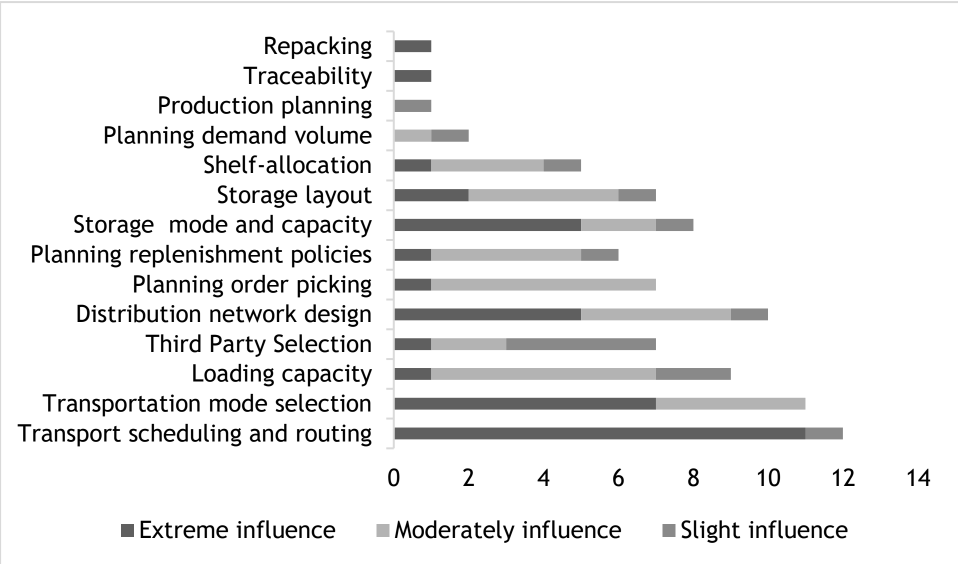

Figure 9: Different levels of influences each logistic activity has on quality.

The last question focusing on Quality Controlled Logistics, was asked to receive feedback on how produce quality information can add value to current logistics activities in the fresh produce industry. The participants shared their feedback and it was then clustered into groups with similar response. As shown in Figure 10, monitoring environmental conditions, transportation management, and supply chain management were mentioned as the most common activities where produce quality related information can create additional value. Four participants mentioned that it will create additional value to improve transparency and visibility through the supply chain, and three participants mentioned it will create additional value to inventory management and quality management.

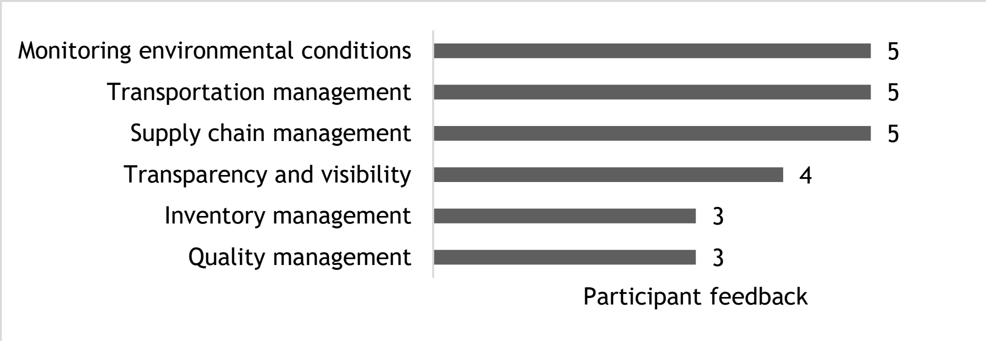

Figure 10: Logistic activities where quality information may add value.

3.3.2 Feedback regarding Internet-of-Things

The following set of questions were asked to the participants to identify their knowledge on the concept of IoT, and whether they believe that IoT-technologies can contribute to assist logistic activities and decision making in the fresh produce industry. The first question gave participants the opportunity to provide some benefits when implementing IoT-technologies in the supply chain. Their feedback was clustered into eight groups as shown in Figure 11. From the feedback, eight participants mentioned that IoT-technologies will assist with the monitoring of environmental conditions, and six participants said it will provide quick access to real-time data and route scheduling. It was mentioned five times that it will provide visible product quality through the supply chain. Other benefits that were mentioned, include optimising supply chain, processes, cost reduction, supplier trust and increased supplier performance, and reducing human error.

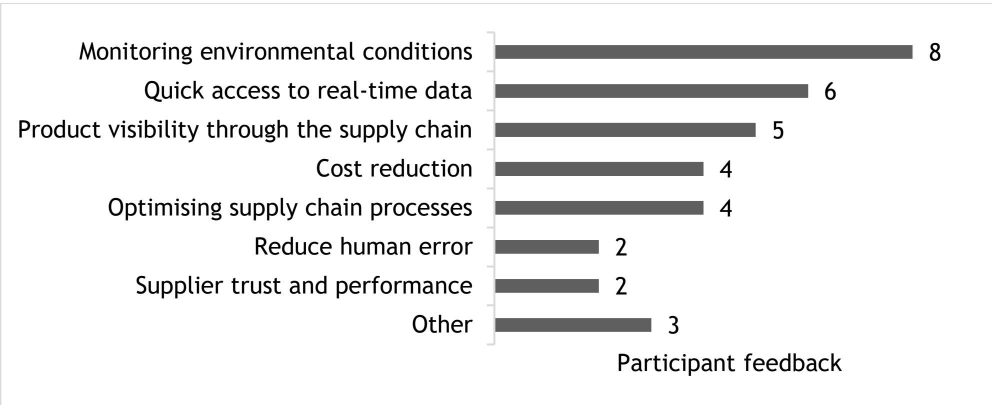

Figure 11: Benefits implementing IoT-technologies in the produce industry.

Next, the participants were asked to provide feedback on how IoT-technologies can add extra value to logistic decisions within the produce industry. Feedback was once again clustered into similar responses provided by the participants. Figure 12 shows the different value creation opportunities that were identified by the participants. Participants mentioned that IoT-technologies can add value to strategic supply chain planning by creating more flexible and adaptive planning, and using data to identify separate market requirements, and developing new business models. Another popular response is that IoT-technologies have the capabilities to make logistic activities more visible and transparent throughout the supply chain. An interesting response that was mentioned six times, is that participant believe that IoT technologies will enhance stakeholder relationships and trust throughout the supply chain.

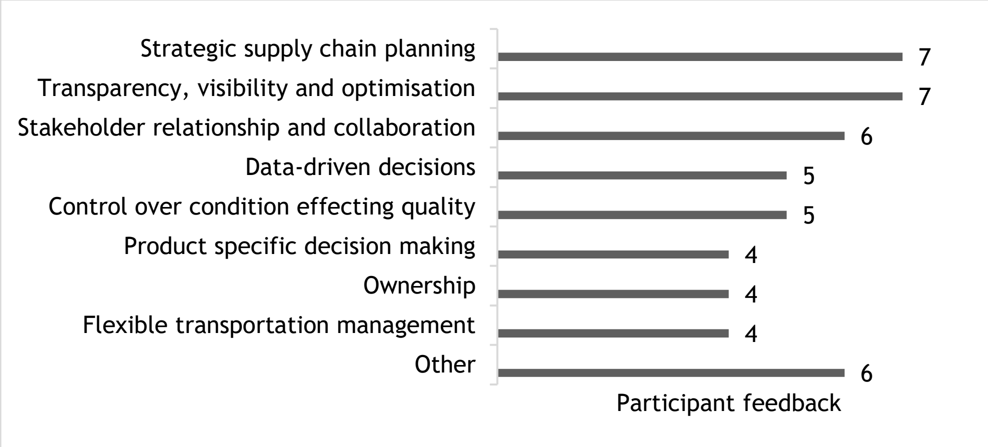

Figure 12: Value creation in the fresh produce supply chain.

Figure 13 shows the feedback participants provided to the question related to identify technical requirements for the implementation of IoT-technologies in the fresh produce industry. Popular feedback from the participants were the kind of network connectivity required, the type of application devices as well as the user interfaces required, and the type of sensing devices and data loggers to capture relevant data. Only two participants mentioned that data security is an important requirement for IoT implementations.

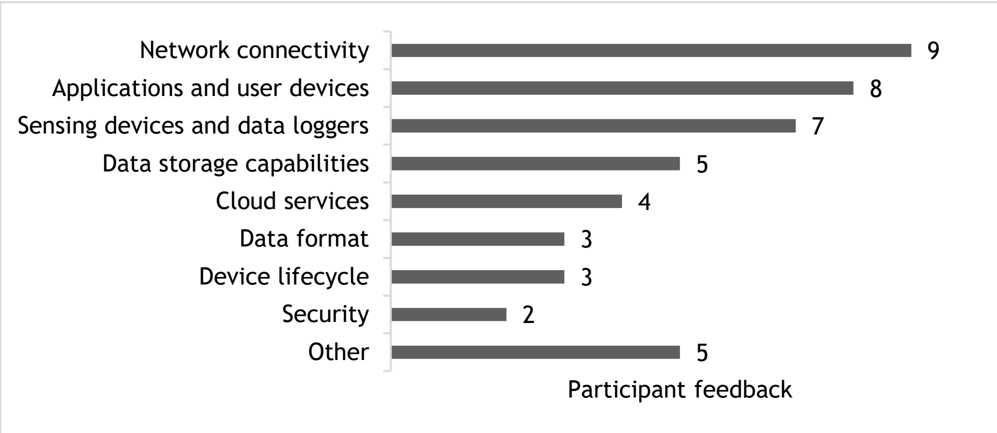

Figure 13: Technical requirements for IoT implementation.

The aim of the last question was to determine what type of challenges the participants believe there are to implement IoT-technologies in the produce industry. From Figure 14, it is noted that acceptance and collaboration to implement IoT-technologies, as well as integrating these technologies with current systems, were the most common challenges mentioned by the participants. The cost of implementation was also mentioned by four participants, but other participants believed that the associated costs to IoT-technologies are not a significant challenge. Other challenges that were mentioned by the participants are the physical installation of the IoT-system, training the users, and receiving valuable information from the collected data.

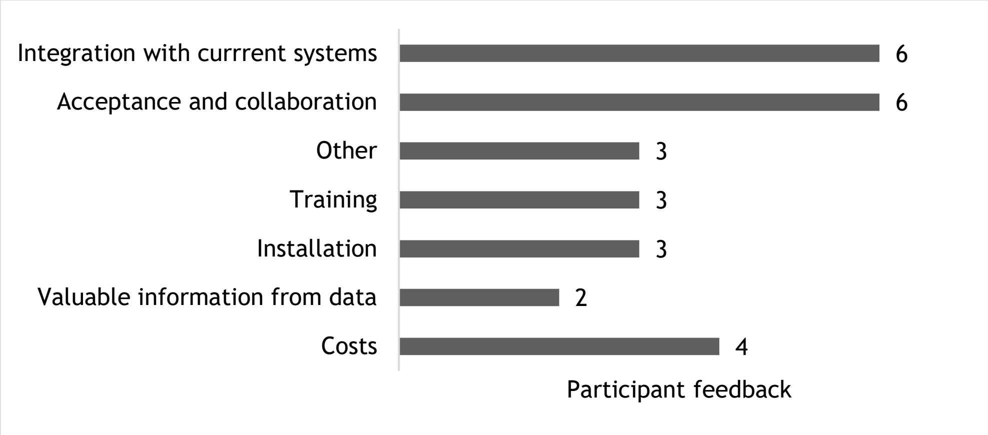

Figure 14: Challenges to implement IoT-technologies.

3.4 Discussion

By analysing the feedback from experts in the fresh produce industry, there seemed to be a positive attitude towards the implementation of IoT-technologies to assist several logistic activities in the fresh produce supply chain. The use of IoT-technologies in the fresh produce industry is not new, since there already exist solutions to monitor environmental conditions. Although it is widely used during transportation management, it is believed that these technologies can create further benefits in the fresh produce industry and will be discussed in the points below.

3.4.1 Temperature management and transportation

From the feedback given by the participants, temperature management, otherwise known as "cold-chain monitoring" during transportation, plays an important role within fresh produce supply chain logistics. Stakeholders in the fresh produce industry realise that inappropriate temperature-management is one of the key reasons why produce are wasted throughout the supply chain. Therefore, transportation companies realise the value of reliable temperature monitoring within different transportation modes. Transport companies have started to invest in solutions such as (i) refrigerated and deep-freeze trucks; (ii) trucks with isolation barriers at the doors; and (iii) temperature recording systems within the trucks, to monitor the temperature conditions while transporting fresh produce to their required destinations. The use of these solutions makes it easier to ensure that temperature stays within acceptable limit, and provides more accurate temperature reading, since temperature logging was done manually in the past.

3.4.2 Monitoring other influences on produce quality

Produce quality depends on both intrinsic and extrinsic attributes. From the feedback, it is realised that companies invest in multiple solutions to monitor extrinsic attributes such as temperature, relative-humidity within transportation and storage infrastructure, and lighting, shock, and vibration during transportation. Although many participants agreed that influences such as ethylene have an influence on produce quality, there have not been many solutions implemented to monitor and track these intrinsic attributes throughout the supply chain. Monitoring intrinsic attributes can provide meaningful information on produce quality, especially when these attributes can be incorporated into shelf-life or prediction models to assist logistic decisions.

3.4.3 Importance of shelf-life models

Participants were asked what type of methods they use to estimate remaining shelf-life of produce, and majority responded that best-before-dates are used. The problem with this method, is that it is a static method and ignores temperature exposure history as well as other conditions affecting shelf-life. To develop more accurate and dynamic shelf-life models, it is required to monitor attributes that influence the produce quality such as temperature, relative-humidity, and ethylene release, depending on the produce characteristics.

Developing accurate quality related shelf-life models can be a game-changer in the fresh produce industry, as it has capabilities to become a useful tool to assist decisions regarding several logistic activities in the fresh produce supply chain. Most warehouses and distribution centres use a "First-In-First-Out" inventory management approach. The problem with this approach is that it assumes the quality of produce arriving the same day at warehouses or distribution centres have equal shelf-life, which is not true due to different conditions they have been exposed to. Knowing the predicted shelf-life based on quality, products can be distributed via a First Expiry-First-Out (FEFO) approach. Another benefit using quality related shelf-life models and the FEFO inventory management approach, is that produce shipment can be distributed more "intelligently" by matching the remaining shelf-life to the required lead time until the shipment reaches the desired location. Not only can it reduce food waste during transportation, but it ensures that remaining shelf-life in a shipment is uniform, meaning the variation of quality is less.

3.4.4 Need for accurate visual inspection

Visual inspection is a fast and common method used to assist quality management, and to decide whether the fresh produce should be accepted or rejected. The problem with visual inspection is that it only reflects visible deterioration and do not consider other influences that reduces quality. The challenge with perishable products is that they usually look fresh until just before they are about to get spoiled. It makes it difficult to distribute correct quality fruit to the various market segments, as good-quality produce may be rejected, or bad-quality produce being accepted. Fortunately, from the feedback provided, participants realise this challenge, and agreed that there is a need to make intrinsic quality attributes more visible and transparent through the supply chain to improve and assist logistic activities such as quality management, better supply chain management, and monitoring environmental conditions to ensure optimal produce quality for end-consumers. The benefits of making produce quality information more visible are numerous since it might (i) improve quality consistency; (ii) reduced waste due to better logistic decisions; and (iii) a higher delivery yield, since produce will be accepted based on more accurate quality information.

3.4.5 Need for pallet-level monitoring

Many companies in the fresh produce industry realise the importance of monitoring environmental conditions, since it influences the quality of produce to some extent, and multiple solutions can be implemented to assist companies. Only a few companies realise that pallet-to-pallet variations exists, hence they realise that environmental monitoring only provide limited produce quality information. To address this problem, new solutions must be created to monitor and act upon these variations, and one method is implementing pallet-level monitoring. Pallets are an effective position to monitor, as it spends majority of its life-cycle with the produce self. Pallet-level monitoring is capable to capture the actual conditions of the produce and provide more accurate data to develop shelf-life prediction models.

Another important benefit of implementing pallet-level monitoring is that it can act upon quality variation and reduce losses. For example, Jedermann et al. [15] mention in a case study that the temperature within pallets during transit is not the same. This result that some pallets may experience quality degradation faster than others. Knowing the quality of produce inside pallets, can change the way several logistics activities such as inventory management, and distribution are executed, and enhance shelf-life optimisation.

4. CONCLUSION

Food waste is a significant issue globally and many initiatives are being researched and implemented to reduce food waste. Concepts such as quality-controlled logistics are promoted within the fresh produce supply chain. It is believed that it can contribute to the reduction of food waste when produce quality is considered whilst determining logistic strategies. Researchers further believe that the IoT-technologies create the opportunity to assist quality control by monitoring the conditions fresh produce are exposed to.

The goals of the questionnaire were to determine whether experts working in the fresh produce industry were familiar with quality-controlled logistics as well to receive their opinion on the use of IoT-technologies in the industry. From the feedback it was identified that most experts have already implemented quality-control activities such as temperature management, since inappropriate temperature management is one of the key reasons why produce is wasted in the supply chain. Experts are also becoming more interested to implement IoT-technologies in the industry. They realise that it creates the ability to collect product specific quality data that can be used to determine the quality of fresh produce more accurately. Furthermore, they believe that IoT-technologies can provide insights to enhance supply chain planning, such as implementing shelf-life models to adapt inventory and transportation management.

There is still limited literature available to gain sufficient understanding on how IoT-technologies and quality-controlled logistics can be combined to potentially reduce food waste along the fresh produce supply chain and to improve overall produce quality. Also, to the researcher's knowledge there are currently no definite framework available to assist fresh produce companies with the implementation of IoT-technologies to improve quality-controlled logistics.

Hence, this paper forms part of an ongoing research towards the development of a framework to assist quality-controlled logistics by using IoT -technology. Further research is currently being done to compare the impact of traditional logistic activities versus quality controlled logistic activities on food waste, which is caused by shelf-life loss. Thereafter a proposed IoT solution will be developed that collects available real-time data that can be used as input to determine dynamic shelf-life estimations of fresh produce. It is believed that the IoT solution will assist quality-controlled logistics, which will contribute to potentially reduce food waste along the fresh produce supply chain.

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